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Technical Insight

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Whole-life costs of a Passivhaus:

Sensitivities of whole-life cost analysis for domestic Passivhaus buildings

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This paper demonstrates that in the majority of scenarios (and even if it costs 10% more to build), a Passivhaus will have lower whole-life costs than a traditional new build. Choice of building services is critical, however, and selecting those with lower maintenance and replacement costs is highly recommended.

The Passivhaus standard for building low energy homes is growing in popularity across the world. When compared to a typical new home, built to UK regulatory standards, Passivhaus demands superior insulation and air tightness, coupled with a mechanical ventilation system, all of which cost extra and can potentially increase build costs. The extra investment can be justified for those with a long-term interest in the building if lifetime costs are considered. In this Technical Insight, published by Encraft's Building Physics team, we investigate the sensitivities which arise when modelling whole-life costs of Passivhaus dwellings.

Whole-life costing analysis accounts not only for capital costs, but also for the total operational (fuel bill) and maintenance costs, which are summed over the lifetime of the building. Fuel price rises, tax and inflation can also be incorporated into the analysis when appropriate. It is a method which can be used to compare a number of cases or scenarios, based on common assumptions, but it is not an exact science and is only as accurate as the information that is put into the model. This Encraft Technical Insight explores the impact of varying assumptions and uses this to generate results which are more robust.

Introduction

Passivhaus, a German certification system for low-energy buildings, is becoming increasingly popular in the UK. The first certified in the UK in 2009, now there are over 324[1] certified Passivhaus buildings including houses, schools and offices and many more in construction. A domestic Passivhaus should save over 77% on space heating when compared with a new build.[2] The energy and CO_2 savings are immediately apparent when comparing a domestic Passivhaus with an annual space heating bill of £66 with that of traditional new build which would be almost £300 per year[3]. However, Passivhaus can cost more to build, with extra investment needed for insulation, air tightness and the ventilation system. The key question is, what does Passivhaus really cost over its lifetime when compared with a conventional house? This is a difficult question to answer as it will vary from project to project due to difference in build cost, maintenance contracts and even choosing the duration over which the comparison takes place. In this paper we explore the sensitivities and options that should be considered when undertaking Whole Life Costing Analysis (WLCA) for a Passivhaus. We present some WLCA results for five cases, all with the same modest floor area (88.5 m^2) as follows:

Whole-life Costing Analysis

Whole life costing analysis (WLCA) is a comparison of whole life costs, which in the case of houses includes;

- capital costs (build costs)
- operational costs (fuel bills)
- maintenance and repair costs (mainly building services, but some building fabric components also need maintenance and repair over the lifetime of the building)

Case	Type	Description
1	Typical new build	Brick cavity wall, traditional new build of average cost[4] with gas boiler for space heating and hot water
2	Timber frame Passivhaus	Timber frame with direct electric space heating, ASHP[5] and solar thermal for hot water and MVHR[6]
3	Timber frame Passivhaus	Timber frame with gas boiler for space heating and hot water and MVHR
4	Timber frame Passivhaus	Timber frame with compact unit which provides MVHR and ASHP for space heating and hot water, all in one unit
5	Cavity wall Passivhaus	Brick cavity wall, traditional new build to Passivhaus standards with gas boiler for space heating and hot water and MVHR

[1] Passivhaus Institute record of certified Passivhaus and Enerphit buildings in the UK http://karten.passiv.de/?q=gebaeude&o=true&l=en_EN
[2] Energy Saving Potential, Promotion of European Passive Houses, May 2006
[3] Based on our PHPP calculations of Case 2a Passivhaus
[4] According to SPONs Architects & Builders Price Book and some data from a Walker Cotter Cost Plan, March 2012
[5] Air source heat pump
[6] Mechanical ventilation with heat recovery

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WLCA Sensitivity Analysis

As is described in the following sections, there can be a lot of variables when performing WLCA. It is important to conduct sensitivity analysis to truly understand the results. We have looked at a series of variables for each of the 5 cases outlined above:

- WLCA lifetimes of 30, 60 and 100 years
- Four different fuel price forecasts (all predicting price rises)
- MVHR filter replacement carried out by professional or by homeowner
- Steel or plastic ductwork
- Including and excluding tax

The effect that each of these has on the final WLCA results is discussed in the following sections.

What is the lifetime of a house?

Whole-life costing analysis is performed over a set lifetime. The duration of this will depend on the perspective of the client. If they are a private homeowner, they may wish to look at the whole life costs over a shorter term (for example 30 years) than a social landlord organisation. A social landlord organisation may wish to examine costs up until the house needs demolishing, which may be in 60-100 years' time, longer than any one person is likely to live in a house.

The lifetime does make a difference the final results. Choosing a shorter lifetime will mean that costs early on (for example the capital costs of the build) will have more of an effect on the whole life costs.

In theory then the Passivhaus, with a higher build cost should come out worse in a 30 year WLCA than a 100 year one. However, the results are not as different as they could be because a Passivhaus tends to have high maintenance and replacement costs, mainly due to the MVHR when compared with our typical new build house (Case 1). This means that over 100 years the maintenance and replacement costs mount up to thousands of pounds, even in today's money.

WLCA Core Principles

There are a number of core principles for WLCA that are important in understanding the results of the analysis

1. **WLCA is only as accurate as the information that is put into the model:** This is a very important point, and as we will see later can change the fundamental outcome of the results.
2. **Common factors are ignored:** Any similarities between the houses do not need to be included in the modelling. For example, the unregulated energy consumption, such as from white goods is assumed to be the same for all houses (as we're comparing the same floor area) and is therefore not included.
3. **Comparison not a prediction:** The results of WLCA should only ever be used to compare different options. Firstly, the costs that come out of WLCA will not include common factors (see point 2) and secondly they will be quoted in terms of net present value (see point 4) and not actual value.
4. **Net present value:** All future costs are converted into a present day value using a discount factor. The discount factor depends on the discount rate and when the cost is incurred in the future.

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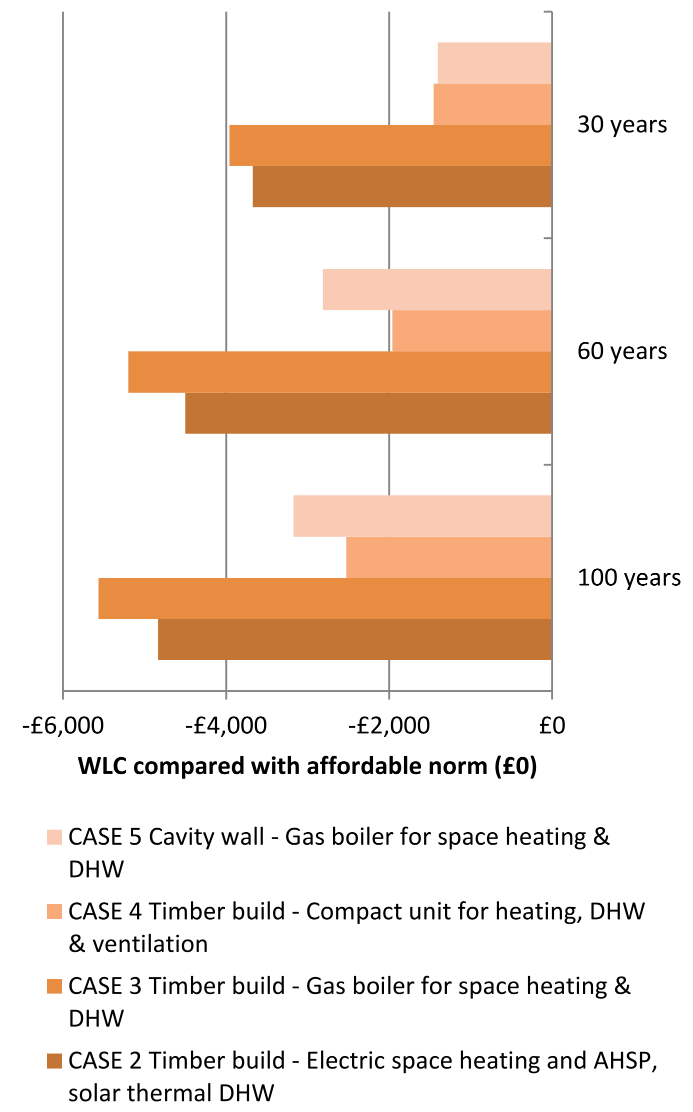
The WLC[7] for the four Passivhaus cases are shown below in comparison with the typical new build (Case 1) for three different lifetimes.[8]

All Passivhaus cases have lower whole-life costs than the typical new build (the typical new build is Case 1, which is set as the baseline, shown as +/- £0 in the graph)**.** Costs become lower as the lifetime of the analysis is extended. This is because of the very low operational costs (fuel costs) outweighing the additional maintenance costs.



Net Present Value

All future costs are converted into a present day value using a discount factor. The discount factor depends on the discount rate and when the cost is incurred in the future.

The interest rate used for discounting is a rate that reflects an investor's opportunity cost of money over time, meaning that an investor wants to achieve a return at least as high as that of her next best investment. Hence, the discount rate represents the investor's minimum acceptable rate of return.

A social housing provider may have an anticipated rate of return similar to public sector projects. This is defined by the Treasury to be 3.5% for the first 30 years, 3.0% for years 31-75 and 2.5% for years 76 to 100.

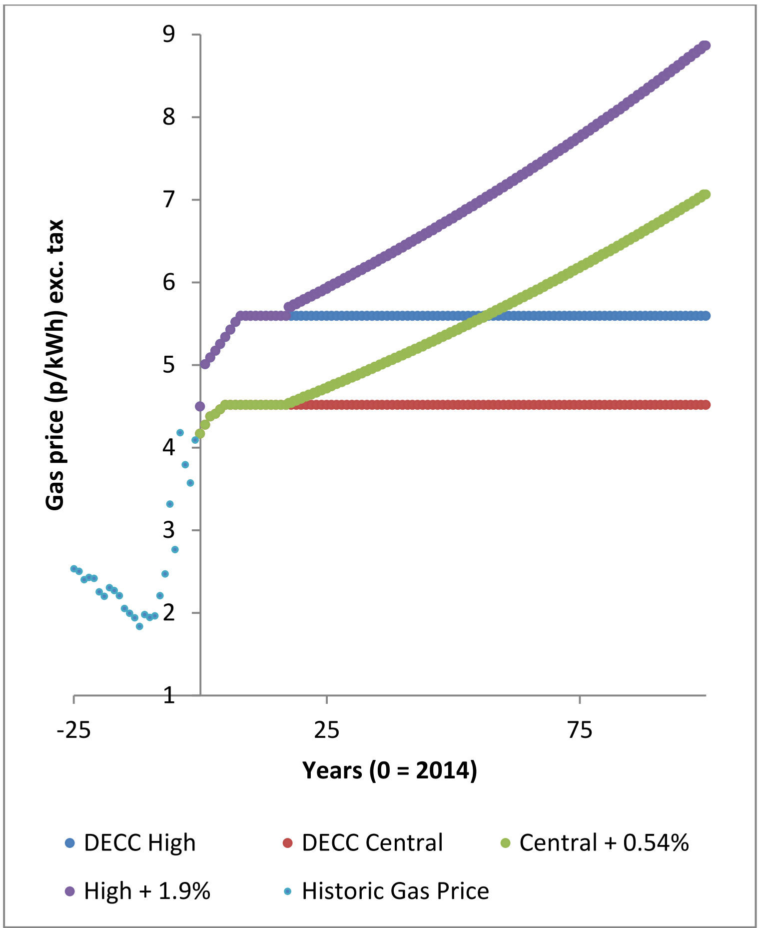
These are the figures we have used in the model and do not include inflation which we have excluded from all costs.

[7] Whole-life costs

[8] These results or obtained using the following assumptions: excluding tax, steel ductwork, homeowner filter change, DECC Central fuel price forecast (see Operational costs).

Fuel costs

The fuel costs are the operational costs for the lifetime of the building. In this paper we have used PHPP[9] to estimate annual energy use for space heating and hot water, including pumps and other auxiliary components (see Operational costs). However, the WLC will depend on future fuel prices and future fuel prices are difficult to predict. We have therefore used series of forecasts[10] to see how future fuel price changes affect the WLCA results. We have developed four fuel forecasts as shown in the graph below.



All the forecasts predict a future price rise. Two (in blue and red) are from DECC's fossil fuel price forecasts to 2030, which have been extrapolated out to the desired lifetime. Two (in purple and green) are also based upon the DECC forecasts but predict a continuous price rise rather than a plateau. Historical data is also shown for the 25 years previously.

Capital costs

Capital costs can be difficult to predict at the early stages of a construction project, however this is the time when WLCA needs to be performed. Any similar capital costs, for example ground works or internal stairs can be ignored in all cases. Only where there are differences in the capital costs do they need to be included in WLCA.

In this paper we have used data from Beattie Passive for their timber frame Passivhaus and known industry averages for the traditional cavity wall constructions. The building services capital costs are directly from the manufacturers, who were also able to give us an idea of installation costs.

The build cost for the typical new build (Case 1) worked out at just over £1,000 per m^2.

As expected, the Passivhaus constructions come out with higher capital costs than our affordable norm. The lowest cost is the timber frame with gas boiler Passivhaus (Case 3) which is 4% more than the affordable norm. The highest costs are the timber frame with compact unit (Case 4) and the cavity wall with gas boiler (Case 5) which are both 9% more than the affordable norm. This seems to fit with what we know about Passivhaus build costs of being around 0-10% more than a traditional build.

[9] Passivhaus Planning Package
[10] Based on DECC 2013 Long-term fossil fuel price forecasts (up to 2030)

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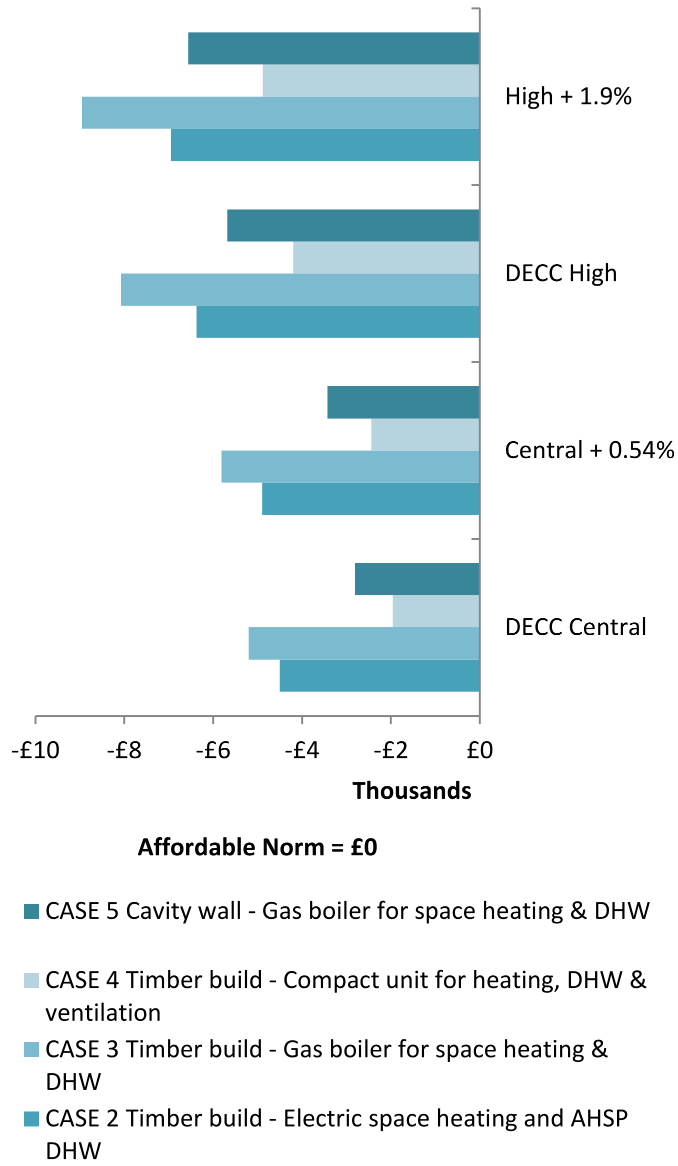
Below is a graph showing the effect of these four fuel price forecasts on the WLCA results for our Passivhaus cases.

All Passivhaus cases have a lower whole-life cost than the typical new build (the typical new build is Case 1, which is set as the baseline, shown as +/- £0 in the graph). A higher fuel price forecast increases the WLC of the typical new build (Case 1) with its higher energy consumption and therefore the Passivhaus cases perform far better in the WLCA.[11]



Operational costs

Fuel bills calculated for the current year, using data taken from PHPP modelling of space heating and hot water are shown below.

Electricity use associated with the running of pumps and similar auxiliary components in the MVHR, boiler and ASHP is also included, but common factors such as electricity used for lighting and white goods are ignored.

	Gas	Elec	Total
Case 1	£562	£101	£663
Case 2	£135	£42	£177
Case 3		£346	£346
Case 4		£284	£284
Case 5	£135	£42	£177

[11] Assumptions for these results are: 60 years lifetime, excluding tax, steel ductwork, resident MVHR filter replacement.

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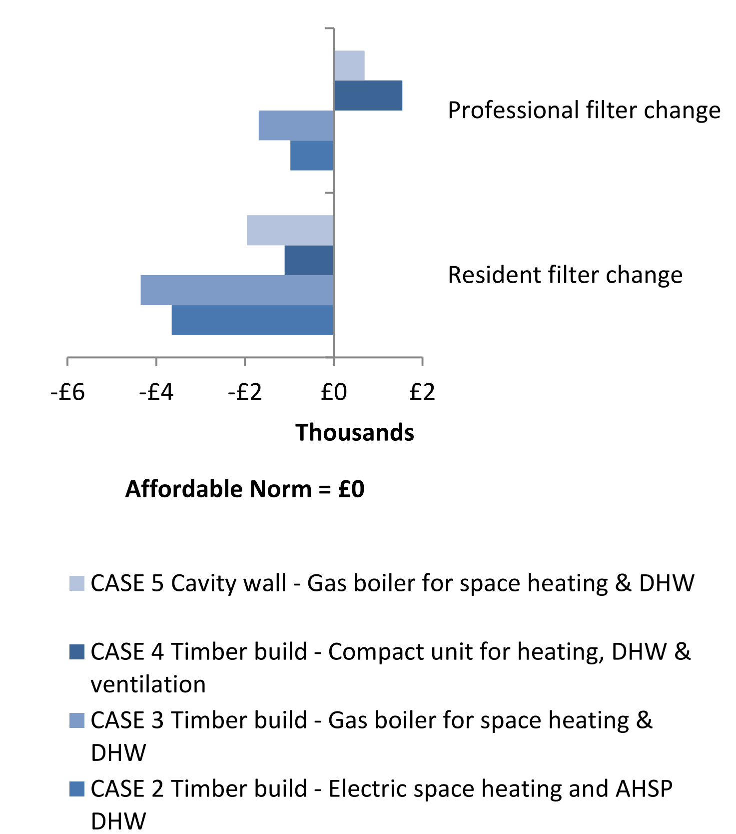
Maintenance costs

Some of the likely maintenance costs are as follows:

- Annual boiler servicing
- Annual gas safety certificate (landlords only)
- 6 monthly MVHR filter change
- 3 yearly ASHP service by specialist contractor

Maintenance costs will vary depending on the client. For social housing providers or private landlords, maintenance costs will fall under their responsibility. However, for private households, some of the maintenance can be done by the home-owner. One particular example, which has a marked effect on the results of the WLCA is the replacement of MVHR filters. The recommended replacement interval is 6 months. The cost of the filters is minimal and replacement can be done by the homeowner. For private landlords or social housing providers, the cost of this can be more than doubled as they would normally send a maintenance operative to replace the filters. This cost adds up over the lifetime of the property (even if filter replacements drop in price, labour costs may not).



Tax and inflation

Tax can be complicated and difficult to predict, so it is often easier to leave it out of WLCA. However if the results are very close, it can be interesting to see the effect that including and excluding tax can have on the calculations. For example, no tax is payable on new-build construction costs, but will be payable on maintenance and replacement costs. This means that including tax on all costs will favour buildings that have higher construction costs but lower maintenance and replacement costs. Including tax for future maintenance and replacement costs will either mean choosing a flat rate (probably similar to today's rates) or, similar to fuel prices, producing a forecast.

Inflation can be removed completely from WLCA calculations since it is so unpredictable. The rate of returns defined by the treasury for public sector projects does not include inflation (see Net Present Value).

The graph left shows the effect on the whole life costs of a resident MVHR filter change and a professional MVHR filter change.[1] The Passivhaus cases 4 and 5 both have higher whole life costs than the typical new build (Case 1) when a professional is sent to replace the filters every 6 months

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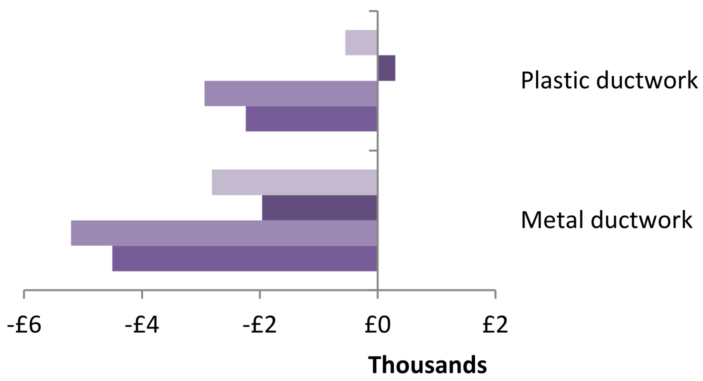
Replacement costs

Most building services (and some of the building fabric components) will need to be replaced within the lifetime of the building. For example, the domestic gas boiler has an average lifetime of 10 years. MVHR components, such as the fan, the heat exchanger and even the ductwork will all need to be replaced. Metal ventilation ductwork, although more expensive, has an average lifetime of 40 years and plastic ductwork only has a lifetime of 15 years.[12] The decision as to whether to go for metal or plastic ductwork can be informed by WLCA.



Some building services components and their typical lifetimes[12] are listed below

Component	Lifetime[12] (years)
Gas boiler	10
ASHP	20
Solar thermal	20
MVHR unit replacement	50
MVHR fan	15
MVHR heat exchanger	25
Steel ductwork	40
Plastic ductwork	15

It makes better financial sense to install metal ductwork than plastic ductwork over the lifetime of an MVHR system (approx. 50 years) due to the cost of taking out the old ductwork and then making good the finishes after new ductwork has been installed. Using plastic ductwork in a Passivhaus, and assuming it will be replaced every 15 years, makes a big difference to the final WLCA results. The graph above shows the WLCA results for the four Passivhaus cases with metal or plastic MVHR ductwork.[13] The plastic ductwork increases the whole life costs of the Passivhaus cases so that in one case (Case 4) the Passivhaus costs more over 60 years than the typical new build (Case 1, which is set to £0).

[12] CIBSE Guide M: Maintenance Engineering and Management, 2008
[13] Assumptions are: 60 year lifetime, resident MVHR filter replacement, excluding tax, DECC central fuel price forecast.

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Conclusion

Considering all the above analyses we can conclude that in the majority of scenarios, a Passivhaus will have a lower whole-life cost than a traditional new build. Choice of building services is especially important as a traditional gas boiler produces lower whole-life costs than an all-electric heating and DHW system (such as the compact unit, or ASHP). Not only is it cheaper to install, but the maintenance costs are lower, as is the cost of gas when compared with electricity.

We have also shown that metal ductwork in a ventilation system is favourable over plastic, even though the product is more expensive to buy. Because the replacement cost is so high, the much longer lifetime of the metal ductwork produces lower whole-life costs.

These analyses clearly demonstrate that it is not sufficient to look at capital costs or annual running costs for buildings in isolation, but that maintenance and replacement costs are equally as important. A series of scenarios should be analysed where data is unknown e.g. such as fuel price forecasts or tax so that the results are well understood. Scenarios (or cases) can also be useful when the design team has a difficult decision to make regarding specification, for example, between a gas boiler and all electric heating. WLCA is a valuable tool in building design, but the results need to be well understood and handled with care.

What is Passivhaus?

Passivhaus is a rigorous energy performance standard and certification scheme for buildings. Benefits of the Passivhaus approach are not limited to energy and whole-life cost saving, the standard also delivers superior thermal comfort and good indoor air quality, as well as demanding a high quality of workmanship in the design and construction and a reduced performance gap.

For more information visit

UK Passivhaus Trust
www.passivhaustrust.org

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